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ANTI-G SUIT PROTECTION AND BODY POSITION

Edwin Hendler, Ph.D., Leonid Hrebien, Ph.D.
and Phillip E. Whitley, Ph.D.
Aircraft and Crew Systems Technology Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974-5000

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22a NAME OF RESPONSIBLE INDIVIDUAL: Leonid Hrebien, Ph.D.	22b TELEPHONE (Include Area Code): (215) 441-1490	22c OFFICE SYMBOL: 60B1

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ABSTRACT

When the pressure delivered to anti-G suit (AGS) bladders was reduced in accordance with the calculated reduction in the height of the vertical hydrostatic blood column, brought about by supinating relaxed subjects, G protection provided by the AGS was greater than that provided when the relaxed subjects were seated upright.

INTRODUCTION

Specif:cations for the anti-G valve dealing with outlet pressures to be furnished during sustained accelerations (G_z) relate only to the usual upright seated body position assumed by pilots flying conventionally configured aircraft. For modern high-performance fighter and attack aircraft, it has been proposed that the pilots be supinated in order to better tolerate the high G loads these aircraft are capable of generating. The study to be described was the second in a series conducted for the purpose of determining the effects upon relaxed G tolerance of some G protective techniques, including use of the AGS and supination.

METHOD

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Six relaxed, G-trained subjects were exposed on the NAVAIRDEVCEN Dynamic Flight Simulator (DFS) to increasing G pulses in order to measure their G tolerance. Acceleration profiles consisted of haversine-shaped onsets and offsets lasting 2 or 8 s, with 15 s plateaus interposed. If the subject successfully tolerated the acceleration profile, the next run was made with the plateau increased by 0.5 G. The subjects wore a CSU-15/P AGS, a liquid cooled vest, and were restrained by a torso harness in the Pelvis and Leg Elevating (PALE) seat. Bio-instrumentation consisted of ECG electrodes and thermistors attached to the torso, a Doppler transceiver fixed over the temporal artery, and an inflatable cuff containing a microphone for the remote measurement of brachial arterial blood pressure. The PALE seat was adjusted to either a 15 or 60 degree seat back angle (Figure 1). G tolerance was measured as the G load and duration which caused constriction of the subject's forward visual angle to 60 degrees, as determined by using the NAVAIRDEVCEN curved light bar (1). The procedure for determining G tolerance was repeated three times per day per subject, each time with a different combination of independent variables. The order of runs and subject exposures was systematically varied throughout the 14 days of testing. For each combination of conditions, control runs were also made when the bladders of the AGS were not inflated. Inflation of the AGS bladders was accomplished using the NAVAIRDEVCEN servo controlled anti-G (SCAG) valve (2) in either of two different operating modes, I and B. In mode B, initial bladder pressurization was greater and occurred more rapidly (see (1) and (2) for further details). The SCAG valve outlet pressure was based upon the following relationship (2):

$$P = 1.5\,(G - 1)\cos(\theta - 15) \qquad (1)$$

where P is outlet pressure in psig and equals zero when $G < 1.5$, G is resultant G load, and θ is seat back angle in degrees. For the seat back angles used in the present study, equation (1) reduces to $P = 1.5\,(G - 1)$ for the upright body position and $P = 1.06\,(G - 1)$ for the supine body position. The pressure gradients of 1.5 and 1.06 psig/G, and others which were about 25 percent greater and lesser, were used in the earlier study of this series conducted in 1982. In the present study (conducted in 1984) pressure gradients about 12.5 percent greater and lesser than 1.5 and 1.06 were used. All of the gradients are shown in Figure 2, and the resulting plots of SCAG valve outlet pressure versus G are given in Figure 3.

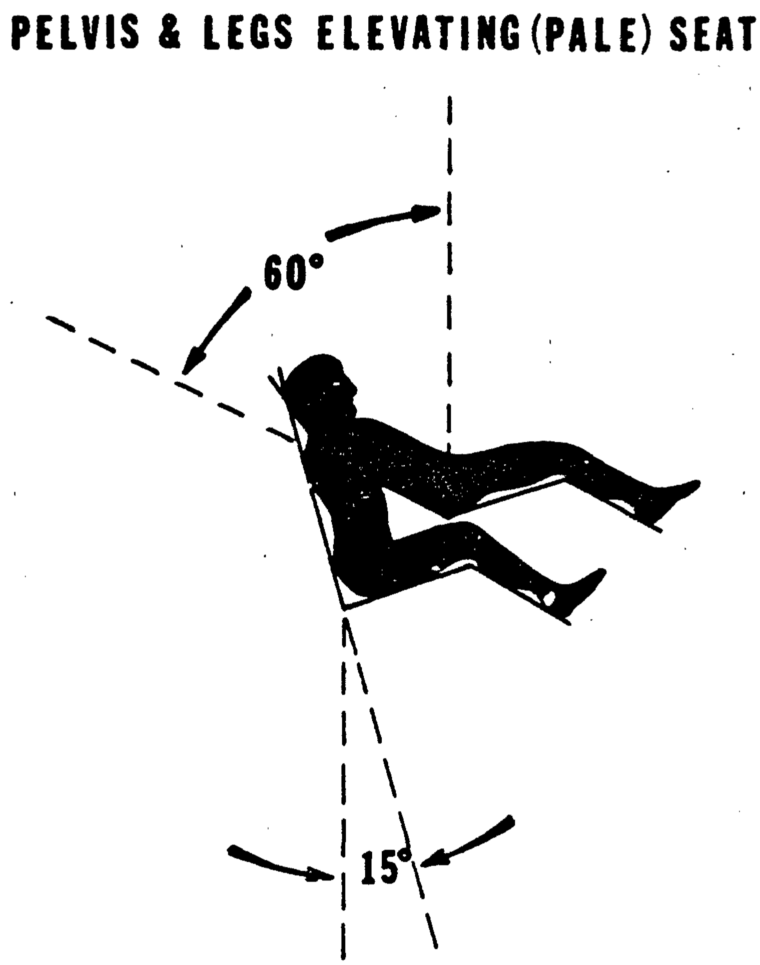

Figure 1 - Diagrammatic representation of body positions assumed by subjects in present (1984) and earlier (1982) studies.

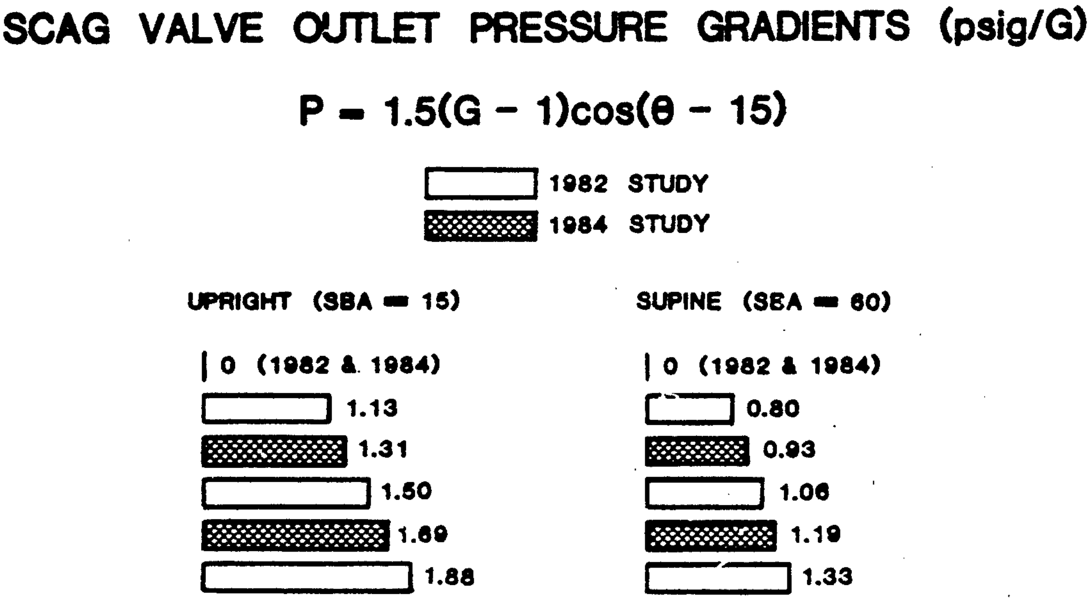

Figure 2 - Servo controlled anti-G valve outlet pressure gradients used in present (1984) and earlier (1982) studies.

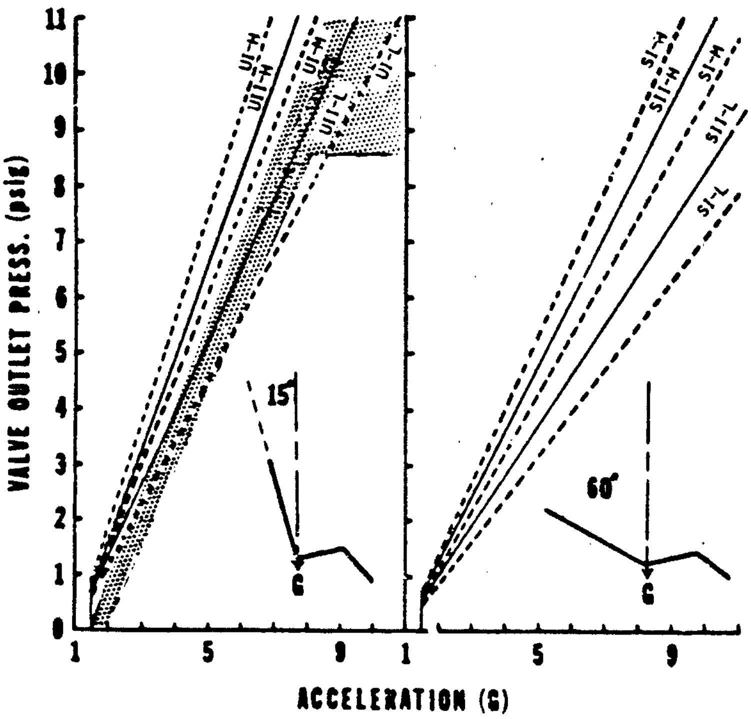

Figure 3 - Anti-G valve outlet pressures as a function of G. U = upright; S = supinated; I = 1982 study; II = 1984 study; H = high; L = low. Shaded area is specified in MIL-V-9370D for stadard anti-G valves.

Following each run in which a threshold G tolerance level was determined, the subjects rated AGS comfort according to a posted scale and they also provided pertinent comments.

RESULTS

G Tolerance: As shown in Figure 4, the two levels for all independent variables were significantly different with respect to mean G tolerance, except for mode of SCAG valve operation. As expected, supination caused the largest increase in G tolerance, with SCAG valve outlet pressure playing the next most important role. As found in our earlier study (1), G tolerance increased directly with SCAG valve outlet pressure for both body positions.

G Protection: G protection was calculated by subtracting G tolerance in the upright body position while using no G protective technique from the G tolerance measured under the same experimental conditions, but using one or more G protective techniques. G protection is shown in Figure 5 for the G protective techniques of supination, torso skin cooling, and bladder pressurization. In contrast to the theoretical G protection based upon the summation effects of individual protective techniques, the black bars represent actually measured mean G tolerance for the three conditions of no pressure, low pressure, and high pressure in the AGS bladders. For all these conditions, measured G tolerance exceeds that which would be expected, based upon a summation effect, or additivity, of the individual protective techniques. When evaluated statistically, the differences between measured and calculated mean G tolerances were significant for both low and high pressure in the AGS bladders. Table 1 shows the G protection provided by the AGS for both body positions and both bladder pressurization schedules. The differences between high and low bladder pressures for both upright (paired $t_{(47)} = 5.45$, $p < .001$) and supine (paired $t_{(47)} = 3.22$, $p < .005$) body positions are highly significant. The difference in AGS protection between the upright and supine body positions is also highly significant (paired $t_{(95)} = 5.86$, $p < .001$).

AGS Comfort: The only data considered in making AGS comfort assessments was that collected during runs in which the AGS bladders were inflated. Overall mean comfort scores are shown in Figure 6 for each subject, and the overall mean score for the group was about 68, indicating a verbal rating between "Fair" and "Good". In order to reduce the initial differences in comfort assessment between subjects, the overall mean comfort scores of the subjects were subtracted from their individual comfort scores to obtain adjusted comfort (AC) scores. The only experimental condition showing a statistically significant difference in AC scores was AGS bladder pressure. Mean AC scores and their standard errors are shown in Figure 7; also shown in this figure are the AC scores obtained in our previous study (1). The results of both studies clearly show that the greater the AGS bladder pressure, the greater the degree of discomfort of the wearer.

DISCUSSION

No attempt has been made to compare the results obtained in studies of the kind described here with those made using other facilities, because

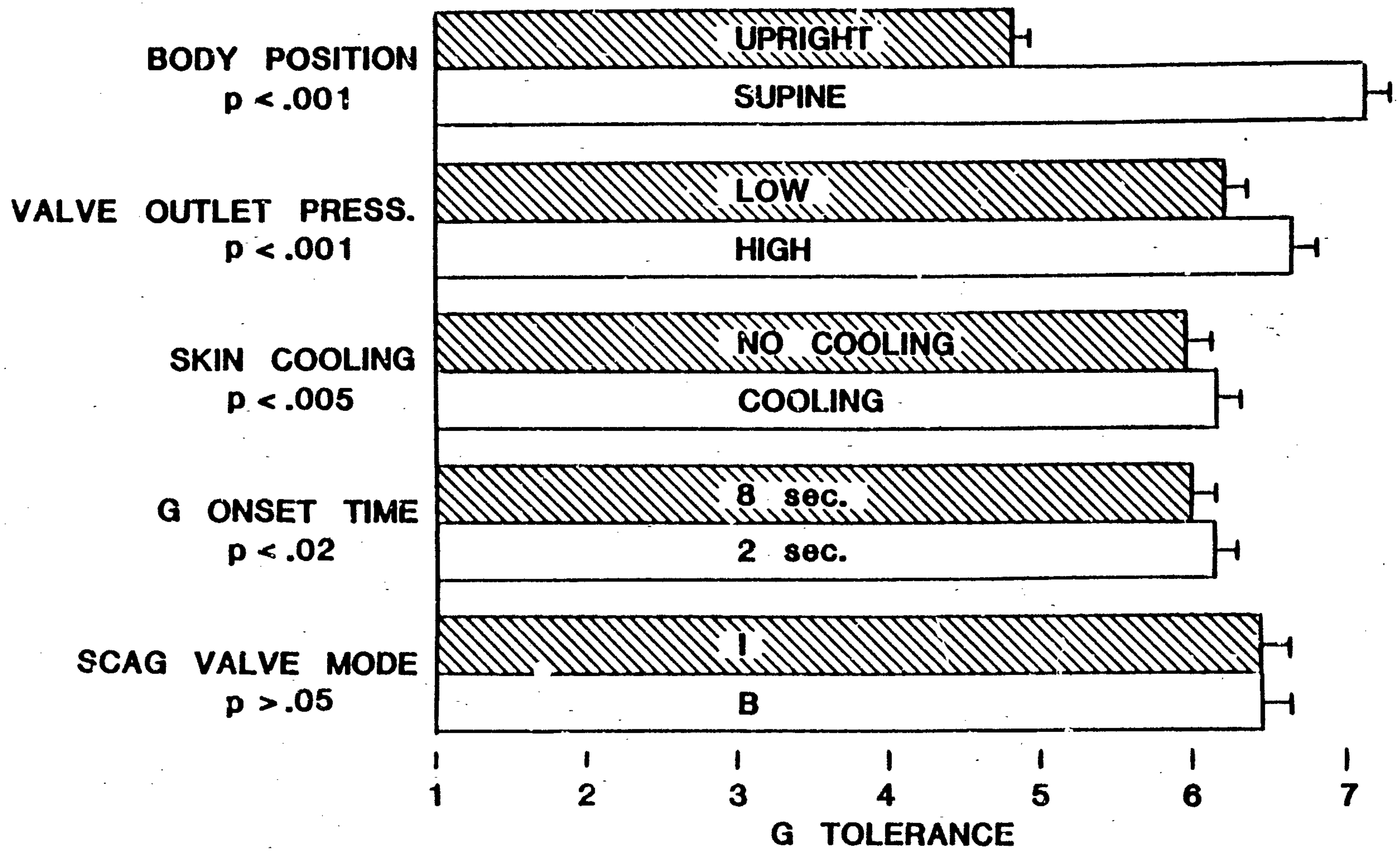

Figure 4 - Mean ± S.E.M. for two levels of independent variables used in present study. Probabilities are based on paired t-tests comparing both levels.

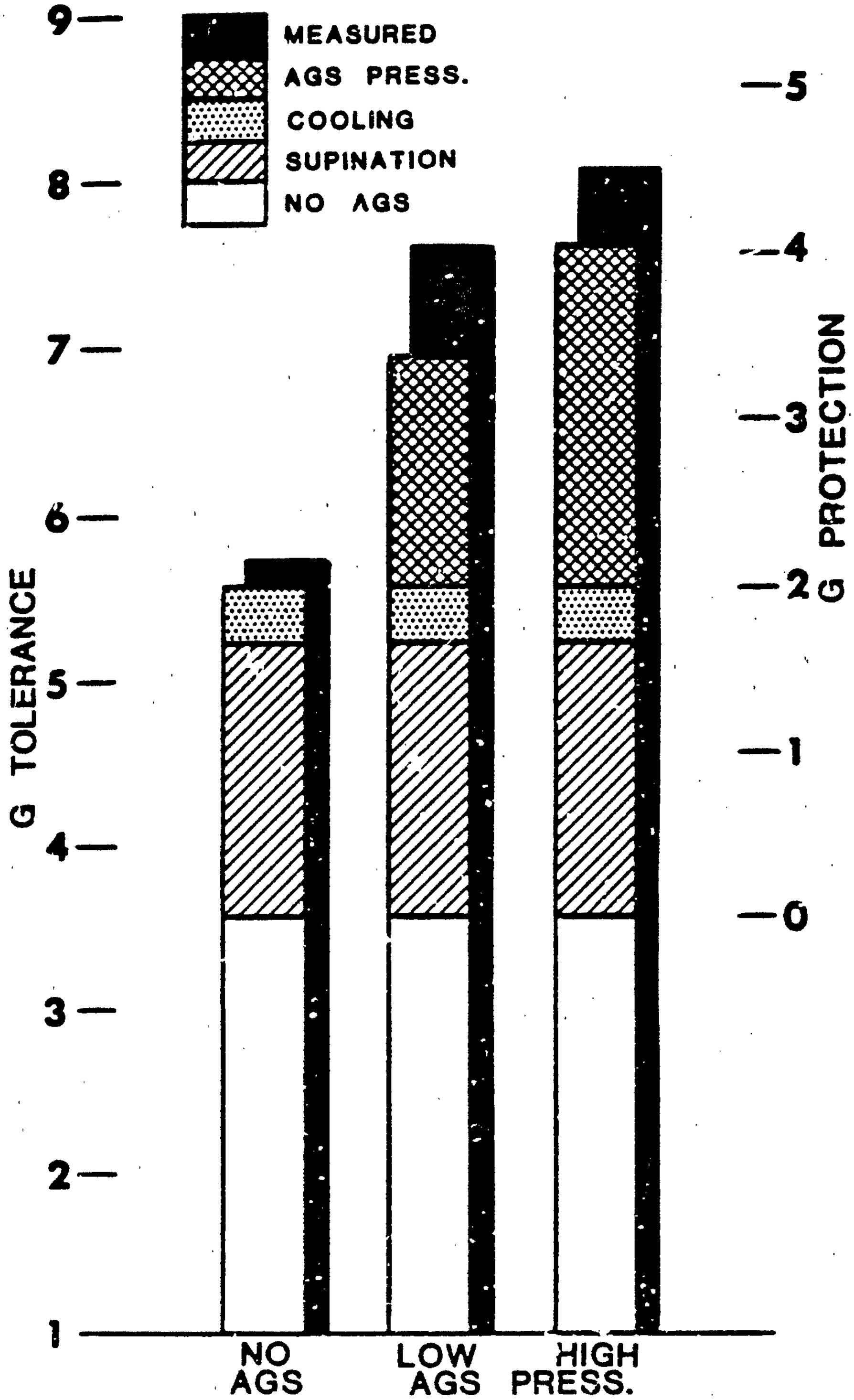

Figure 5 - Comparison of increases in G tolerance (G protection) in present study, obtained by summing of individual components compared to measured G tolerance (black bars).

TABLE 1. G Protection Provided by Anti-G Suit

(Mean $\pm$ S.E.M., N=48)

AGS BLADDER PRESSURE	BODY POSITION	
	UPRIGHT	SUPINE
LOW	1.24 ± 0.08	2.01 ± 0.15
HIGH	1.74 ± 0.09	2.36 ± 0.16

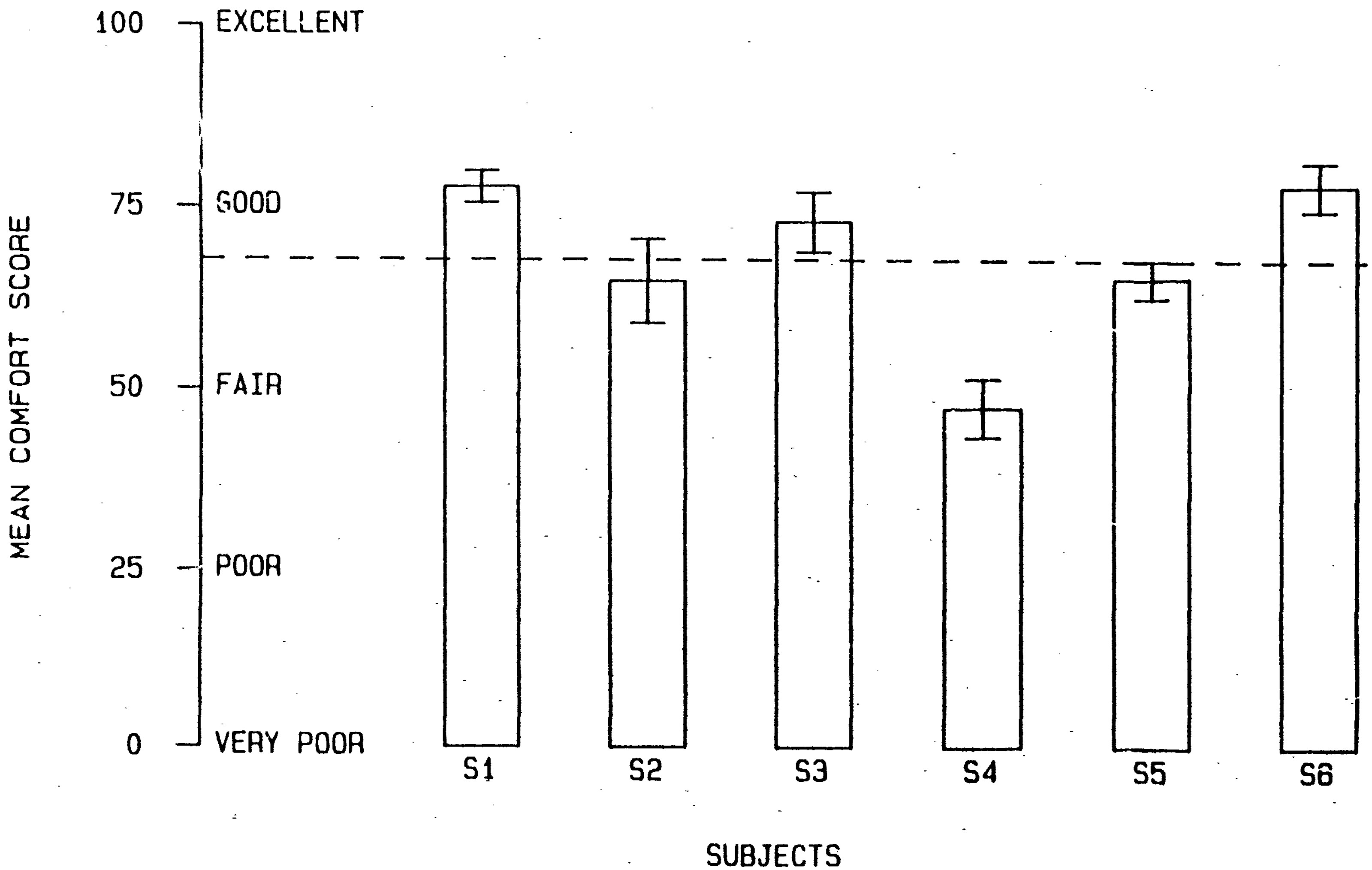

Figure 6 - Mean ± S.E.M. of AGS comfort scores for subjects in present study.

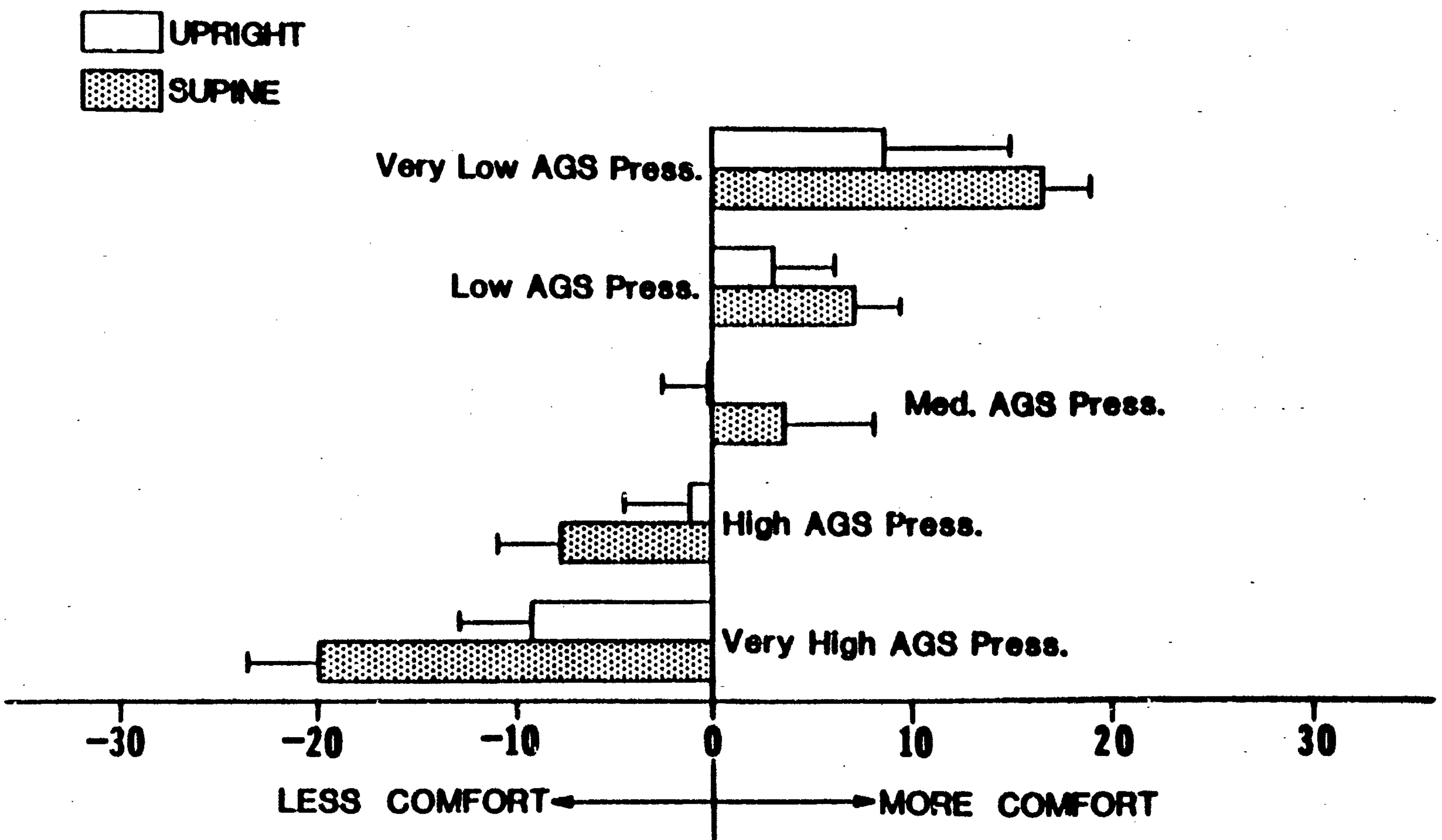

Figure 7 - Mean ± S.E.M. of adjusted AGS comfort scores. I = earlier study (1982); II = present study (1984).

of the many differences in techniques and procedures. However, in addition to our earlier study (1), some comparisons with those of Crosbie (2) and Cohen (3) can be justified on the basis of significant similarities in methods and equipment. In addition to G protection obtained from the AGS and supination, Cohen's subjects also employed the M-1 maneuver; Crosbie's subjects were not supinated, but did use the AGS and M-1. In none of these earlier studies was there evidence that the combination of two or more G-protective techniques resulted in greater G protection than that expected from merely summing their individual contributions. The present study is therefore the first conducted recently at NAVAIRDEVCEN to suggest that a synergistic effect is realized when supination (and torso cooling, in this case) is combined with AGS bladder inflation at two different levels of pressurization. Speculation on why the protective affect of the AGS should be enhanced during supination is made difficult, due to our limited understanding of the physiological basis of its action. Since supination in the PALE seat includes elevation of the pelvis and legs, as well as extension of the latter, it is apparent that blood pooling in the lower extremities was probably reduced even before the application of centrifugal G. If inflation of the AGS bladders was then to impede blood flow to the lower limbs during G, a larger blood volume may have been made available to increase stroke volume and thereby enhance G tolerance. In this connection, Seaworth et al (4) recently reported that in supinated subjects wearing the AGS in a one G environment, bladder inflation caused increased systolic and mean arterial pressures, with a weak correlation to an increase in end-diastolic volume. Finally, the question of pressurization of the AGS bladders must be considered. All of the pressurizations used in the studies compared above have been based upon the application of equation (1) to the output of the SCAG valve. The pressure gradient of equation (1) was derived empirically, with 1.5 psig/G providing the optimum combination of G protection with subject comfort. From the results of this and our previous study (1), it does appear that selection of this pressure gradient is justified. Modification of the pressure gradient by the cosine of the seat back angle minus the retinal-aortic angle is based upon the premise that pressure applied over skin areas covered by the AGS bladders has a directly proportional effect on cerebral arterial pressure. Thus, if the vertical heart to head blood column is reduced by 30 percent in changing from the upright to the supinated body position, then reducing AGS bladder pressure by 30 percent should still provide for adequate cerebral circulation without compromising comfort. Our present results would argue that this is not the case, and that in the supinated body position, less pressure than that based on equation (1) could be used in the AGS bladders to provide G protection, and that this would also result in increased comfort.

REFERENCES

1. Hendler, E. and Hrebien, L. Factors affecting human tolerance to sustained acceleration. SAFE J. 14:6-10, 1984.

2. Crosbie, R. J. A servo controlled rapid response anti-G valve. SAFE J. 13:10-16, 1983.

3. Cohen, M. M. Combining technqies to enhance protection against high sustained accelerative forces. Aviat., Space and Environ. Med. 54:338-342, 1983.

4. Seaworth, J. F., Jennings, T. J., Howell, L. L., Frazier, J. W., Goodyear, C. D., and Grassman, E. D. Hemodynamic effects of anti-G suit inflation in a 1-G environment. J. Appl. Physiol. 59:1145-1151, 1985.